# Henri Dutrochet (1776–1847): An Unheralded Discoverer of the Cell

*Christian Nezelof, MD*

BOTANY has made immense contributions to the progress of medicine, not just through the introduction of medicinal plants, such as digitalis, cinchona, opium poppy, and various molds, but also through the notion of clonal proliferation, the deciphering of the laws governing the transmission of hereditary characteristics, and the isolation of the first known viruses from tobacco leaves, to mention only a few examples. However, from this seemingly endless list, one major contribution is often overlooked: the identification of the cell, which is the basic structure of living matter. This was the work of several investigators: R. Hooke, H. Milne-Edwards, H. Dutrochet, and T. Schwann. Among them, Henri Dutrochet (1776–1847), a self-taught French medical doctor, is probably the least recognized. The aim of this article is to relate the life of this independent investigator and show his contribution to the identification of the cell as the basic building block of plant and animal tissues.

Henri Dutrochet was born on November 14, 1776, in the Château de Neons, on the banks of the Creuse in Poitou. This property belonged to his father, Count Louis du-Trochet, a member of the country gentry, and of the Order of St Louis, who served as a captain in the Roi-Infanterie Regiment. His mother, born Marie de Gallois, belonged to the "bourgeoisie." Heiress to several properties, she brought considerable affluence to the family. She also took an enormous interest in her children's education. Henri, their eldest son, was preceded by a sister and followed by two brothers and two more sisters.

Because his father was occupied with military affairs and frequently absent, Henri's mother moved her children to Charreau, a family property in Neuville-sur-Brenne, a small village near Chateau-Renault, in Touraine. The house was large and comfortable (essentially a small château) with extensive grounds and forests as well as a watermill. It soon became the home base for the Dutrochet family and was to play a crucial role in the development of young Henri's future interests.[1]

Henri had been born with bilateral club foot, which was treated and permanently cured by a local bone setter before he was 6 months old. In 1785, when he was 9, Henri entered the Collège des Oratoriens in Vendôme, a prestigious religious institution which several years later would become the alma-mater of Honoré de Balzac. We know little about his studies; however, the countless upheavals associated with the French Revolution (1789–1793), such as riots in protest of food shortages, conscription, and inflation, the replacement of the gold-standard by the "Assignats," as well as the flight or execution of various nobles, undoubtedly upset the peaceful life at Charreau. Fortunately, the house, which was somewhat removed from the main Vendôme-Chateau-Renault-Tours road, was relatively spared by the starving plunderers. Nevertheless, Count du-Trochet, Henri's father, who had attended the General Assembly of local aristocrats in Amboise, was forced to flee. For joining the party of conspirators, he was subsequently exiled to England. Consequently, all his property, including his Château in Neons, was confiscated. Benefiting from the protection of some friends who had remained influential in local affairs, Madame Dutrochet renounced the "du" particle in her name, a symbol of nobility, and managed to obtain the status of "war-window." Thus, she was allowed to stay on in Charreau with Henri and her three daughters. However, Henri's two brothers, loyal to the family's military and aristocratic tradition, joined the Royalists and rebels who had installed their camps in Brittany and Normandy. For personal reasons, Henri had at first preferred to remain in Charreau, but he later made an attempt to enlist in the Navy. Travelling through

*From Paris, France.*
*Address reprint requests to Christian Nezelof, MD, 27, rue Gazan 75014 Paris, France.*

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countryside devastated by uprisings and plundering, he made his way to Rochefort. Once there, he was repelled by the strictness of military discipline, the dangers of life at sea, and the limited future offered by a position as steersman. So, he gave up his plan of a naval career and returned to his mother in Charreau where he did "nothing other than waste time, hunt, and suffer from the futility and emptiness of such a life."[2]

Henri was then 24 years old and spent a large part of his time collecting plants, an activity which under the influence of Jean-Jacques Rousseau had became very fashionable. The binomial nomenclature of plants introduced by the Swede Linnaeus gave a real scientific character to this leisure activity. The collection and classification of plants led Henri to meet Doctor Petitbeau who owned a house in the vicinity. In fact, Petitbeau lived in Paris and was a surgeon at the Hôpital des Enfants Malades (Children's Hospital), a new name given in 1807 to a religious institution, previously called the Maison Royale de l'Enfant Jésus, which cared for orphans and deprived children. Petitbeau easily convinced Henri that he should study to become a medical doctor, a profession perfectly suited to the young man's intellectual potential and social position. He began his medical studies in 1802, and in 1804 was accepted as an Interne des Hôpitaux de Paris after a selective examination, established 2 years earlier by Bonaparte. He spent almost all of his internship in the Hôpital des Enfants Malades (Fig 1). This post-Revolutionary period was a time of intense intellectual activity, characterized by the dawn of the Romantic movement (René de Chateaubriand was 36 years old) and, in particular, by the development of scientific concepts, which had been advanced by scientists such as Jussieu, Lamarck, and Buffon. In this effervescence of ideas, the almost metaphysical notions of mucous inflammation, spontaneous generation and particularly the "Force Vitale" were recurrent themes in scientific discussions.[3]

In 1806, Dutrochet defended his thesis on a new theory of phonation.[4] Pushed by his brother-in-law, General Perron, and submitting to the family's military tradition, he reluctantly joined the Imperial Army in 1808. He served as an ordinary army physician, and participated in the disastrous Spanish campaign led by Joseph Bonaparte, Napoleon's brother. In Burgos, Henri fell victim to an epidemic of dysentery and expected to die. Completely disillusioned with life and the army, he was repatriated in a very precarious state of health which he managed to maintain and even aggravate to receive a permanent discharge. Finally, after many difficulties, his military unfitness was declared. It must be said that as both a son and brother of military men and destined to live in a time dominated by the endless Napoleonic wars, Henri Dutrochet, who was at heart deeply antimilitaristic, found himself in a very uncomfortable position (Fig 2).

**Figure 1.** Entrance of the Hôpital des Enfants Malades where H. Dutrochet was an intern from 1804 to 1806.

Back in Charreau, with his mother, and once again puttering about in his garden, he regained the calm that he had always cherished. Reading widely, he happened upon a book written by a priest, Lazzaro Spallanzani (1729–1799). Spallanzani was not only a distinguished cleric but also a doctor of Natural Science in Pavia. He studied the digestive and respiratory processes in various animals, the complex fecundation mechanisms in frogs and toads, and had contributed, along with Antony Leeuwenhoeck (1632–1726), to the discovery of the presence of countless living animalcules in stagnant water. Reading these reports fascinated Dutrochet. Eager to observe for himself the phenomena reported by Spallanzani, he acquired a rudimentary microscope of the type available at that time, transformed a garden shed into a small laboratory, and trained one of his gardeners as a

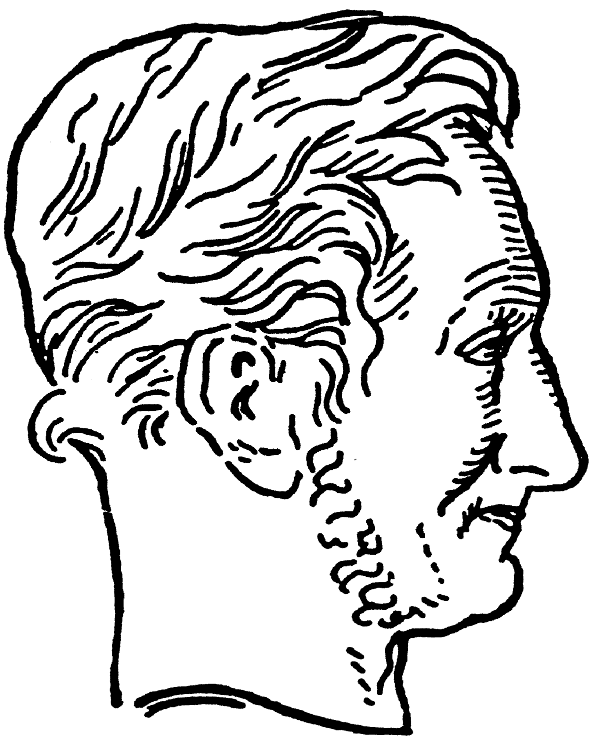
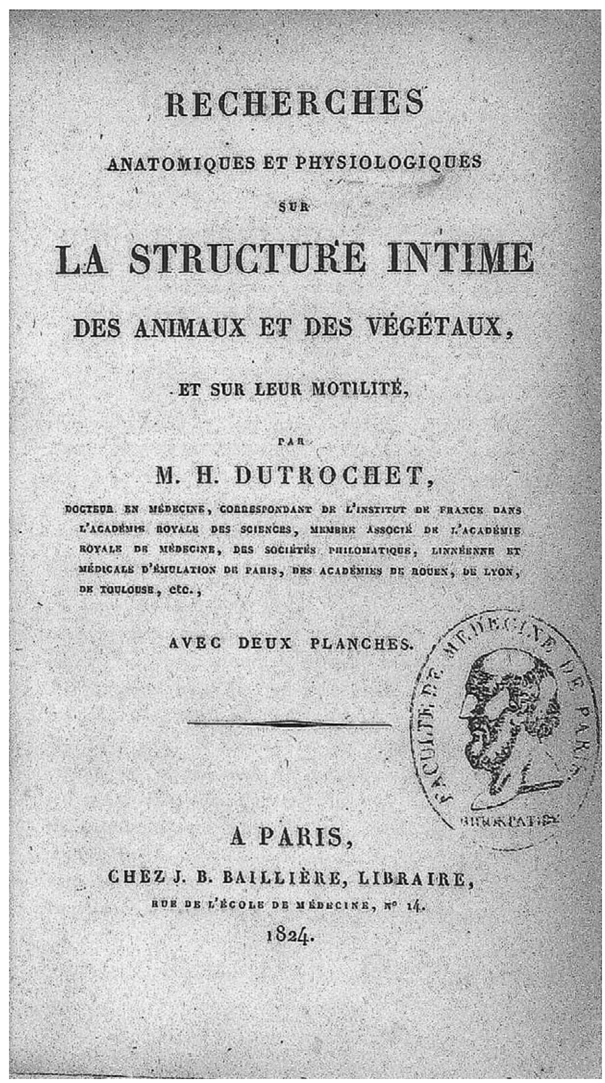


Figure 2. Drawing of the profile of H. Dutrochet after a medallion by David d'Angers in 1842. (From Henri Dutrochet, médecin et biologiste, honneur de la Touraine, by Emile Aron.)

technician to assist him. With simple equipment, he attempted to reproduce Spallanzani's findings and obtain a comprehensive overview of what was really taking place in his garden. He was soon to observe the moving animalcules in stagnant water, just as they had been described and he became particularly interested in the rotifers, a special variety of protozoa that seemed to be in a state of perpetual circular movement. This endless mobility observed through the microscope fascinated him and led him to think that it could well be a direct expression of the famous and elusive "vital force" and, hence, one of the means of studying it. He was also puzzled by the force that pushed the leaves and roots of plants to grow respectively towards or away from sunlight, a phenomenon that persists even in untypical circumstances. Thus, he was firmly convinced that a better understanding of the phenomenon of life required a better analysis of various events underlying and controlling movement. As early as 1824, in his book entitled "Anatomical and Physiological Research on the Elementary Structure of Animals and Plants and Their Mobility" (Fig 3),[5] Dutrochet wrote explicitly: "Life, as far as the physical order is concerned, is nothing more than movement; and death is simply the cessation of this movement. Studying the rules that govern vital motion in animals encounters insurmountable difficulties because of the extreme complexity of the underlying external and internal factors responsible for it. However, the investigation is much easier in plants. Plants will probably provide most of the scientific answers to the main questions concerning life." It was from this angle that Dutrochet chose to initiate his investigation into the basic structure of



RECHERCHES

ANATOMIQUES ET PHYSIOLOGIQUES

SUR

LA STRUCTURE INTIME

DES ANIMAUX ET DES VÉGÉTAUX,

ET SUR LEUR MOTILITÉ,

PAR

M. H. DUTROCHET,

DOCTEUR EN MÉDECINE, CORRESPONDANT DE L'INSTITUT DE FRANCE DANS L'ACADÉMIE ROYALE DES SCIENCES, MEMBRE ASSOCIÉ DE L'ACADÉMIE ROYALE DE MÉDECINE, DES SOCIÉTÉS PHILOMATIQUE, LINNÉENNE ET MÉDICALE D'ÉMULATION DE PARIS, DES ACADÉMIES DE ROUEN, DE LYON, DE TOULOUSE, etc.,

AVEC DEUX PLANCHES.

A PARIS,

CHEZ J. B. BAILLIÈRE, LIBRAIRE,

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1824.

Figure 3. Front page of the book in which H. Dutrochet provided a description of the cell as a basic structural unit of vegetal tissue.

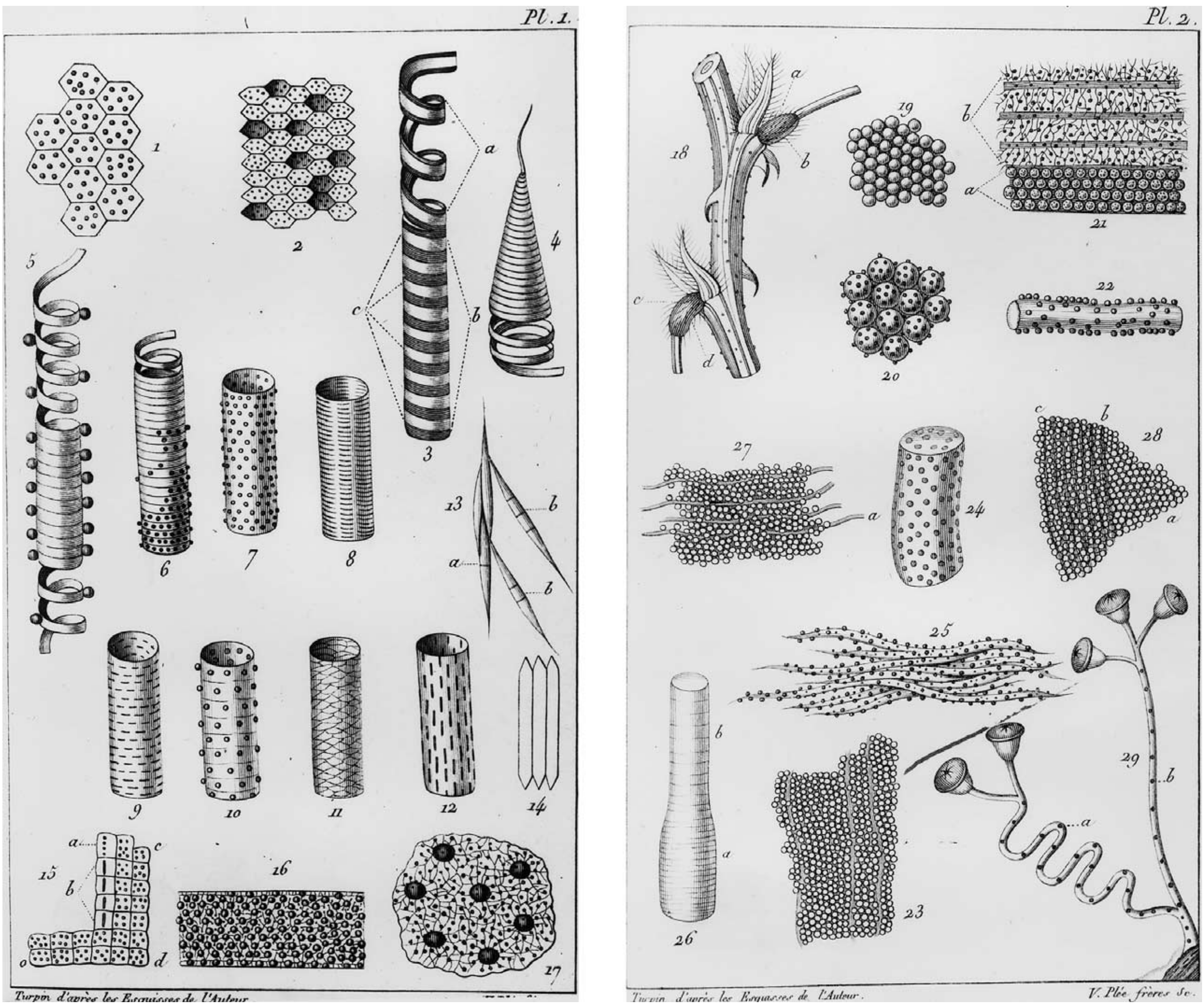


**Figure 4.** Reproduction of the drawings by Turpin based on sketches by Dutrochet demonstrating the shapes of the cells and the straight and spiral structures thought to be the site of the circulation of the sap. (From *"Recherches anatomiques et physiologiques de la structure intime des animaux et des végétaux et sur leur mobilite,"* JB Baillière ed, Paris 1824)

plants. He added, "I was looking for a means of making the study of plant anatomy easier. I succeeded in doing this by using a very simple procedure. Since the compact and opaque nature of its components is the main obstacle to its microscopic observation, I put fragments of the plant, *Mimosa Pudica,* into a vial containing nitric acid and plunged the vial into boiling water. With this procedure the constituent parts of the plant tissue lose their cohesiveness, become transparent and can be easily be studied." It is certainly worth emphasizing the simplicity of this methodologic approach. Twenty years earlier, it had allowed X. Bichat to break down various organs and demonstrate they were made up of different types of tissue that clearly could not be seen with the naked eye. With this simple technical approach, Dutrochet discovered an unimagined world. "When the raw matter of the *sensitiva* or any other plant is subjected to boiling in nitric acid, it is possible to see the cells dissociate from each other and appear as individual units and vesicles that keep their shape. . . ." Vegetal matter is entirely made up of cellular tissue. Its constituent cells generally appear to have a regular hexagonal shape. In certain areas, their shape may be irregular (Fig 4). This sentence, written in 1824, represents a milestone in the history of the concept of the cell.

Because of the lack of accuracy of certain translations, the rarity of illustrations, and particularly the use of the same terms with different or ambiguous meanings (ie, cellular tissue was regarded either as tissue made up of multiple cavities visible to the naked eye [subcutaneous tissue] or as a tissue made up of tiny microscopic elements) the use of the terms of globules or corpuscles without any reference to their size or shape) because also of the refraction artifacts generated by the crude optical equipment of the time, it is difficult, as is rightly emphasized by H. Harris[6] to know precisely what the first investigators saw or did not see. For these reasons, determining who exactly first described the cell as an elementary unit has always been and is still the subject of lively debate.

The name of Robert Hooke (1635–1703) is frequently put forward. He was secretary of the Royal Society and perused the scientific letters of A. Leeuwenhoek and benefited from the use of a microscope based on those designed by the same Leeuwenhoek. Indeed, in 1665, he reported (with illustrations) that a thin piece of cork was made up "of an infinite group of small boxes or bladders of air" suggesting some similarities with the cubicles or "cells" occupied by monks in monasteries. However, Hooke was mainly an astronomer and reported this observation in *Micrographia*,[7] article that included a hodgepodge of several various descriptions of insects and larvae. Moreover, these observations remained isolated and Hooke failed to draw any conclusion from them. Later and more contemporary to Dutrochet, two French scientists investigated on the elementary structure of living matter: François Brisseau de Mirbel (1776–1857) and Henri Milne-Edwards (1800–1885). De Mirbel was mainly a botanist. He became director of the Imperial Gardens and Greenhouses and made several scientific contributions. He reported on the presence of straight or spiral-shaped vessels, which he called "tracheas" and singled them out as the structures (or channels) responsible for conveying the sap. Consequently, he did not pay much attention to their cellular context. Milne Edwards was an MD and zoologist. In 1823 he presented a thesis entitled "Anatomical and physiological research on the elementary structure of the main animal tissues."[8] Although he had the privilege of using the Adams microscope, one of the best available at that time, he reported that the muscles of frogs and other animals were made up of an "agglomeration of independent globules." The drawings that he reproduced (Fig 5) from the different animal tissues were much like those previously reported by Arnold and Malpighi. These globules were found to be not only independent but also of uniform size, 1/300 mm. This unexpected uniformity led Studnicka and Harris[6] to think that Milne-Edwards had not really seen cells, but some halations induced by the illumination. The comparison of the drawings contained in the thesis of Milne-Edwards and those in the masterwork of Dutrochet demonstrates clearly that these two authors did not see the same structures. Whereas those of Milne-Edwards are made up of arrays of round, regular, compact, and almost opaque corpuscles (Fig 5), those of Dutrochet showed groups of geometrical, apparently empty structures which he explicitly called "cells." In the accompanying text, he pointed out that "those cells are of hexagonal shape in some areas and of irregular shape in others. . . When one subjects the tissue of the *Sensitiva* or any other plant to boiling in nitric acid one can see all its cells dissociate and consequently appear as complete vesicles that maintain their shape."[4] It is clear that Dutrochet did not see the nucleus. However, even in his first publication and although he did not use any staining and sectioning technology, he pointed out the presence in the wall of large cells of "spherical transparent, greenish bodies resistant to nitric acid and capable of concentrating light." Contrary to Mirbel, he did not regard these bodies as pores but either as small cells or, still obsessed by the spontaneous movement theory, as "nervous corpuscles."[4] Today, based on these descriptions, it is not clear whether these spherical bodies mentioned by Dutrochet were in fact nuclei or not.

Already in his first publication and a fortiori, his subsequent papers including microscopic investigations of animal tissues, Dutrochet differentiated clearly from his predecessors and contemporaries in that he did not regard living matter as a variant of froth or as a uniform and compact matter criss-crossed by various pipes and channels and holed with cavities, but rather as made up of individual cells. "So the cells," he wrote, "are vesicles simply aggregated without any continuity; their original shape is globular. It is only because of the peripheral, equal and mutual compression exerted on

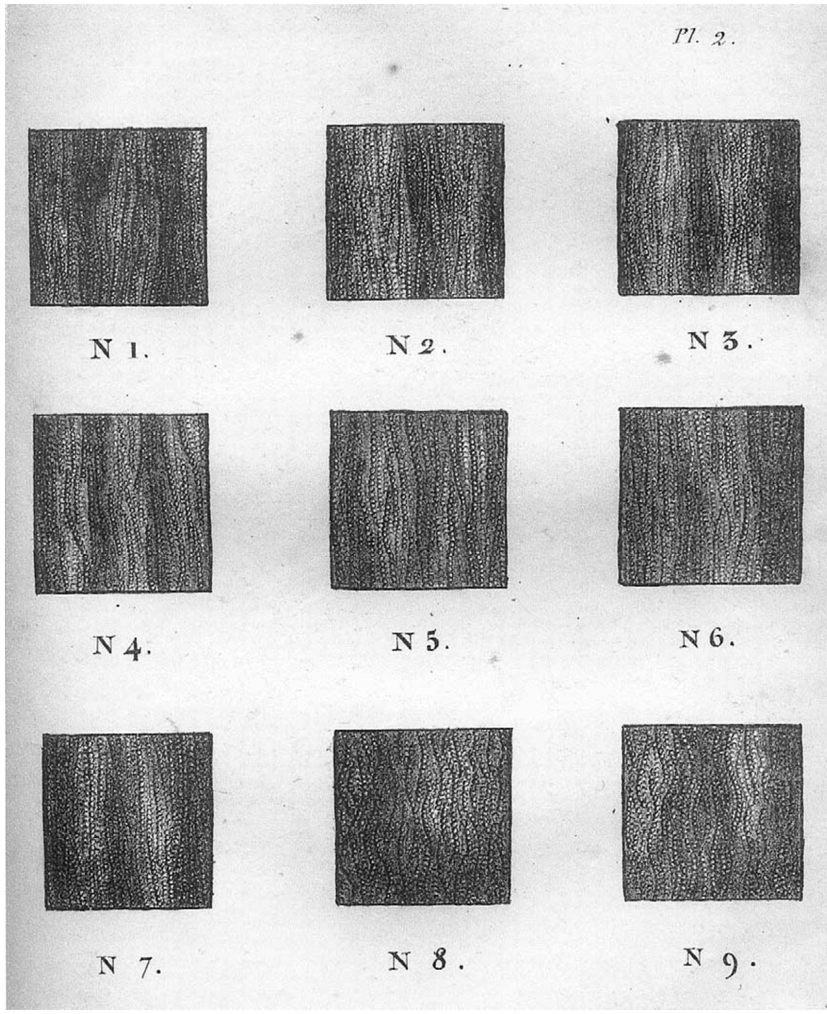


**Figure 5.** Reproduction of drawings made by H. Milne-Edwards (1823) on the cellular tissue of the man (1), dog (2), rooster (3), frog (4), carp (5), peritoneum (6), intestinal mucosa of the dog (7), conjonctive of the dog (8), and conjonctive of the beef (9). Note that these drawings represent globular structures taken at the same 1/300 magnification. Compare the uniform and compact pattern of these globules with the drawings made by Turpin in Dutrochet's book (1824). (From *H. Milne-Edwards. Mémoire sur la structure élémentaire des principaux tissus organiques animaux.* Thèse, Paris, 1823)

them, that they often seem to have a symmetrical and polyhedric shape."[4]

Convinced that vegetal matter is made up of independent units, that its structure is cellular, Dutrochet wanted to know whether his observation could be extended to animal tissues. Using a similar dissociating methodology, he started investigations on snails, frogs, and eels, all of which were readily available in his garden. Because they were so large, Studricka said, he recognized long before J.E. Purpinje, the cells in slugs' heads and rightly hypothesized that they were of nervous origin and involved in movement. Later, adopting the same method he had used to break down plant tissues, he also found cells, albeit smaller, in liver and kidney tissue. "The basic similarity," he wrote, "of cell parenchymatous organs in frogs is such that it is almost impossible to determine microscopically whether the tissues originate in the brain, liver, spleen or kidney. . . So all animal organs are made up of the same cellular tissue which is modified in diverse ways. . . This structural uniformity suggests that the various organs differ only in the nature of the substances contained within the vesicular cells. . . It is within the cell that the secretory process distinctive to each organ occurs. . ." "What a variety," he marvelled, "exists among the physical and chemical properties of cells that can produce the essential parenchymatous substances that make up the fruit, leaves, flowers and roots of the many plants throughout the world. . . It is difficult to conceive that such an astonishing diversity of products could be the work of one simple organ: the cell. . . If one compares its very simple morphological appearance with the extreme diversity of the veritable nature of its products, the cell appears to be the basic building block of organization."[2]

In these descriptions, although he did not recognize the nuclei he nevertheless expressed some premonition or anticipation of their existence, when he said "This observation proves that the globular corpuscles that compose the parenchymatous organs of vertebral animals are indeed cells of very small size, in the walls of which one may even detect smaller corpuscles, if the microscope could penetrate into the depth of the infinitesimal."

Moreover, as emphasized by Harris,[6] Dutrochet had not only a morphologic but also a physiologic approach to the cellular concept. Admitting that each cell had its own membrane, Dutrochet, fascinated by the *Force vitale* and the circulation of the sap and the dynamic exchanges between fluids in general, recognized "that the passage of fluids from an empty organ to another implied the crossing of two contiguous walls" and raised an obvious problem. To his eyes, the previous identification of vessels and various channels by numerous investigators did not offer a satisfactory explanation and, as mentioned earlier, the existence of pores in the walls was disproven by Dutrochet himself. Those observations led Dutrochet to develop and document an original hypothesis on the phenomena underlying the circulation of fluids through the apparently leakproof walls of empty organs which could perhaps extend to cells, although he did not express this last point explicitly. Indeed, he postulated that this circulation was related to the existence of currents, themselves caused by differences in density between two fluids. He called these phenomena "endosmosis" or "exosmosis" from the Greek οσμοσ: impulse, movement.[9,10] In recognition of this major contribution, the Académie des Sciences awarded him the "Prix Montyon." This discovery brought Dutrochet more public acclaim than the identification of the cell for which he has remained largely unrecognized, even in France.

In addition, through his work on cells and osmosis, Dutrochet identified "vagabond cells" in eel tails, anticipating the Wanderzellen that Conheim was to describe several decades later. He also suggested that certain lifeless structures, such as feathers, were originally composed of living cells. He postulated that the growth of an organ was mainly related to the formation of new cells. His curiosity led him to various other areas such as the movements of algae, the structure of the foetal membranes among birds and reptiles, the positions of the stars and meteors, the structure and regeneration of bird feathers, and bloating in cattle among others. He took a keen interest in the agricultural activities of his small village. His advice must have been appreciated because he was elected mayor. He was obviously hard working, dividing his day between municipal activities, gardening, scientific investigations, and the writing of numerous scientific notes that he sent regularly to the *Académie des Sciences.* The notes reported, in a conversational style, what he had observed. He never hesitated to contradict previous findings and fluently expressed the ideas suggested by his investigations.

This full schedule left little room for a sentimental life: it appears that he was very much attached to his mother. Moreover, it must be remembered that he had been a brilliant young medical doctor, and so he enjoyed the company of P.F. Bretonneau, a highly esteemed local physician who had first identified typhoid fever and diphtheria. Bretonneau lived near Dutrochet in Saint Cyr sur Loire and the two men shared a common interest in botany. When a severe cholera epidemic struck in Touraine, killing 21 people in Chateau-Renault, Dutrochet lent a hand to his colleagues in treating the victims.

Dutrochet endeavored to make Charreau a haven of peace where he could devote himself to work. Like many aristocrats, he naively believed that Napoleon Bonaparte would eventually restore their privileges and help them to recover their properties. The execution of the Duc d'Enghien in 1804 opened their eyes and provoked their indignation. His father, who in the meantime had become the Marquis du Trochet, was never to recover his Neons property nor to be reinstated in the army. It was not until the collapse of the Empire in 1815 that he received his war pension.

Prone to frequent headaches and easily fatigued by travelling under the harsh conditions of the time (the Paris-Tours railway line began operating only in 1846). Dutrochet was reluctant to absent himself from his property and leave his mother alone. Only his desire to acquire more efficient instruments prompted him to travel to Geneva and later to the south of France to obtain an achromatic microscope made by Prevost.

The death of his mother in 1833 brought considerable changes in the peaceful regularity of his daily life. Whereas he had hitherto mailed his notes to the *Académie des Sciences,* he then decided to present his observations in person at the Monday meetings. He postulated for a permanent seat at the Academy and left the Touraine for a small rented apartment on Helder street in Paris. There, he became acquainted with the famous scientists of the time: Georges Cuvier, father of comparative anatomy; Lamarck, inventor of the term biology; and, above all, Etienne Geoffroy Saint Hilaire, who became a Professor of Zoology and was to found the menagerie of the *Jardin des Plantes.*

Thanks to the support of Geoffroy Saint Hilaire, who helped to overcome some resistance from the board, he was finally elected as a permanent member of the Academy. Moreover, Geoffroy Saint Hilaire introduced him to a charming as well as wealthy lady, Madame Angelique Geoffroy, the widow of one of the best-known physicians at the Hotel-Dieu (Paris) who had died 8 years earlier.

Dutrochet was 57 years old when he married Angelique and settled down in a confortable Paris town house, located at 4 rue Braque in the Marais. Gaining confidence, thanks to his colleagues' respect and the admiration of the young pupils whose scientific zeal he stimulated, he began a new lifestyle, participating in both scientific meetings and brilliant social events. However, he maintained his interest in botany and his curiosity regarding the phenomena associated with the life and growth of plants.

Each summer, he enjoyed accompanying his wife, now Madame Du-Trochet (she had insisted on restoring the particle) to her estate in Noroy, near Villers-Cotterets, 80 kilometers north of Paris. There, although complaining about the weather, he settled into his small laboratory and resumed his research on the intrinsic thermogenesis of plants.

As his reputation grew, he was invited several times to deliver talks and lectures at the Royal and Horticultural Societies in London.

On February 4, 1847, while he was checking the proofs of his forthcoming publications, he was stricken by hemiplegia and died at 71 after a life described as a "long day of continuous labor."

Indeed, the major treatises on the history of medicine often mention the name of Theodor Schwann (1810–1882), as the discoverer of the cell as the essential unit of living matter. In fact, when Dutrochet published his book in 1824, Schwann was still a teenager and had not yet joined Johannes Muller's staff in Berlin. Not until 1839, when he was 29, did Schwann publish his dissertation on the structural and functional similarities between animal and vegetal tissues.[11] As stressed by many historical authors, Schwann failed to mention Dutrochet and his contribution. The well-known French-German rivalry that prevailed at that time could account for this omission. Reciprocally, in his latter publications, Dutrochet did not mention the name of Schwann either. The main conclusions of Schwann's work were taken up and further developed by his friend, Jacob Schleiden (1804–1881) who gave a precise description of the nucleus.[12]

To evaluate the personal contribution of each of these investigators, it is important to take into consideration not only the chronology but also the historical context and the level of development and optical performances of the microscope which had improved considerably in the first part of the 19th century.

From the available publications, it is clear that several scientists have contributed to establishing the cellular structure of living matter and to individualizing the notion of the cell unit. However, it is also clear that Dutrochet was the first to go beyond simple microscopical observation and use a scientific approach separating in an almost modern way material, methods, observation, and quoting the observations of other investigators, to obtain an answer based on hard physical evidence to a question which was regarded at the time as almost metaphysical. Furthermore, his research was not episodic, but unlike the others was methodic and persevering and prolonged over many years. For these reasons as pointed out by A.R. Rich,[13] J. Pickstone,[14] J.M. Wilson,[15] and more recently by H. Harris[6] and G. Dhom,[16] the important contributions of H. Dutrochet should be acknowledged and in particular his major role in the paternity of the cell should be recognized.

In writing to Geoffroy Saint Hilaire, the famous embryologist, "nature possesses a uniform plan for the intimate structure of all organized beings," Dutrochet incidentally subscribed to a metaphysical concept of that time namely that all organisms were made up of myriads of tiny individual units or "monads" (Leibnitz) or microscopic animals each of which sacrifices its individuality for the welfare of the whole (Oken). Likewise, he anticipated the modern notion that extreme diversity can originate from the variable combination of simple and apparently similar elements, following the example of the letters of the alphabet or musical notes.

With Dutrochet, our understanding of the structure of living matter definitively changes. The living or one living tissue such as flesh, leather, and wood were no longer classified according to their use or physical properties, but according to the types of cells of which they were composed.

The hidden structure of living matter had been revealed. The era of pathologic cytology could now begin.

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